Introduction To Time Series and Forecasting

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Practitioners and researchers in engineering, physical, biological, economic, natural and social sciences are all concerned with the analysis of a sequence of observed data. The desirable goal of such a quantitative analysis of data is to provide a succint but informative definition of the underlying system in the form of a mathematical model. This model can be used to analyse the system and predict its behaviour under a changing environment. The information yielded by an analysis can further be employed to alter possible factors and variables in the system to achieve an optimal performance .

This book deals with system modelling and forecasting based on an ordered sequence of observed data. Unlike an earlier book of the authors, called: *Time Series: Theory and Methods*, referred to as TSTM, the present book has as prerequisites only a knowledge of basic calculus, matrix algebra and elementary statistics, being intended for upper-level undergraduate students and beginning graduate students.

The purposes of this text are to present the concepts of time series analysis in a manner that is friendly even to the reader who lacks a sophisticated background in mathematical statistics and to help the reader learn the art of time series modelling and forecasting by means of detalied examples.

The book contains ten chapters, four appendices, bibliography and an index. Also, a time series package enabling the reader to reproduce most of the calculations in the text, and to analyse further data sets, is included on the diskette which accompanies the book. The main topics of the book are as follows.

Chapter 1 serves as an introduction to time series analysis and builds the general framework of the book. Examples of time series, objectives of time series analysis, some simple time series models, stationary models and autocorrelation function, estimation and elimination of trend and seasonal components and testing of estimated noise sequence are the main topics discussed in this chapter.

Chapter 2 deals with stationary processes. It presents the basic properties of this class of processes, linear processes, autoregressive and moving average (ARMA) processes, the properties of sample mean and autocorrelation function, forecasting stationary time series using Durbin-Levinson and innovations algorithms, and the Wold decomposition.

Chapter 3 continues the discussion, started in the previous chapter, on an important parametric family of stationary time series, that is the ARMA processes. It also presents the autocorrelation and partial autocorrelation functions of the ARMA processes and forecasting on this class of processes.

Chapter 4 deals with spectral analysis. The main topics are spectral densities, the periodogram, time-invariant filters, and the spectral density of an ARMA process. This Chapter can be skipped over by readers without any loss in the continuity of the presentation.

Chapter 5 discusses the modelling and forecasting with ARMA processes. The book offers an expanded treatment of these subjects due to their importance in the field. It starts with preliminary estimation of ARMA model parameters using Yuke-Walker, Burg, innovations and Hannan-Rissanen algorithms, and continues with the maximum likelihood estimation, as an efficient instrument for obtaining good estimates of model parameters. The next step of the modelling methodology consists of diagnostic checking based on the graph of residuals, sample autocorrelation functions of residuals and different tests for residuals randomness. The final topics this

Chapter deals with are the forecasting and model order specification with Final Prediction Error (FPE) criterion and with a bias-corrected version of the Akaike Information Criterion (AIC).

Chapter 6 deals with nonstationary and seasonal time series models. The main topics are the class of autoregressive integrated moving average (ARIMA) models for nonstationary time series, identification techniques for these processes, unit roots in time series models, forecasting ARIMA models, seasonal ARIMA models, and regression with ARMA errors.

Chapter 7 starts with some examples of multivariate time series and discusses second-order properties of such time series, estimation of the mean and co-variance function, multivariate ARMA processes, best linear predictors of second-order random vectors, modelling and forecasting with multivariate autoregressive processes (Whittle's algorithm) and cointegration.

Chapter 8 deals with the state-space models for time series. State-space representations, the basic structural model, state-space representation of ARIMA models, the Kalman recursions, estimation for state-space models, state-space models with missing observations, the EM algorithm (an iterative procedure for maximizing the likehood when only a subset of the complete data set is available), and generalized state-space models (parameter- and observation-driven models) are the main topics discussed in this chapter.

Chapter 9 is focused on forecasting techniques and three forecasting algorithms are presented: the ARAR algorithm, as an adaptation of the ARARMA algorithm (the ARMA fitting step is replaced by the fitting of a subset AR model to the transformed data), the Holt-Winters, using a set of simple recursions that generalize the exponential smoothing recursions for generating forecasts of series containing a locally linear trend, and the Holt-Winters seasonal algorithm, that extends the Holt-Winters algorithm to handling data in which there are both trend and seasonal variations of the known period. The last section of this Chapter is devoted to the application of a forecasting algorithm.

In **Chapter 10** of the book a variety of topics of special interest is discussed: transfer function models, designed to exploit for predictive purposes the relationship between two time series, intervention analysis, which allows for possible changes in the mechanism generating a time series, nonlinear time series analysis, continuous-time ARMA processes and fractionally integrated ARMA processes ("long-memory"processes).

A number of topics included in this book have not been considered in the authors' previous book. They include: harmonic regression, the Burg and Hannan-Rissanen algorithms, unit roots in time series models and regression with ARMA errors, structural models, the EM algorithm and generalized state-space models, with application to time series of count data, the Holt-Winters and ARAR forecasting algorithms, intervention analysis, nonlinear and continuous-time models.

As said before, the book includes four appendices. **Appendix A** summarizes random variables and probability distributions. **Appendix B** offers some statistical complements on least -squares estimation, maximum likelihood estimation, confidence intervals and hypothesis testing. **Appendix C** contains some basic notions on mean -square convergence. **Appendix D** provides a detailed example for the analysis of a univariate data set using the software package ITSM96, which was developed by the authors. The presentation focuses on getting ready and on data preparation for modelling, model fitting, model testing, prediction and model properties evaluation.

Ample and informative references are given at the end of the book.

The book includes, at the end of each chapter, numerous homework problems, at various levels of difficulty. The problems are an intrinsic part of the text, and a good deal of them should be attempted by the reader who wishes to master the material.

A unique feature of the book is made by the extensive software package and the data sets used . The programs require an IBM-PC compatible computer and DOS or Windows operating systems, standard facilities. Use of the computer package requires little prior knowledge in computing. As the programs are all menu-driven , the reader can immediately apply the techniques described in the book to time series data, with minimum time spending on the computational and algorithmic aspects of the analysis. The book could also be used in conjunction with other computer packages for time series analysis and forecasting. One should emphasize that the programs included are not "toy programs". The software is suitable for use in serious applications and the readers are encouraged to go beyond the study phase and use themselves the software .

To make the underlying theory accessible to a larger audience, the authors stated some of the key mathematical results without proof, but they made sure that the logical structure of the development was otherwise complete. The book would rather have accessibility and clarity than mathematical sophistication.

The book is intended for students, researchers and practitioners who have had little statistical training, but who like to study time series analysis and forecasting methods, or are confronted with decisions based on these methods. Of course, those with more rigorous statistical training, but not familiar with time series analysis and forecasting, will certainly have a profitable reading.

This book can be didactical material in an advanced undergraduate course or beginning graduate course on time series analysis and forecasting. Such a course could be delivered at a business school, a department of economics, or could be part of an engineering curriculum. Social science departments (education, psychology, public health, medicine) could also introduce such a course in their curriculum. It is important to remember that the book is an application-oriented book.

The material is very well -organized, presented with clarity, and the reader's understanding is helped with many examples. It is worth mentioning the fluency of the style, the absence of printing errors and the accuracy of graphical material (122 illustrations), which make the book an agreeable companion. From the pedagogical point of view, this book deserves being known.

Finally, I reiterate that this is a very good book in terms of the topics selected and the approach made, and I heartily recommend it to researchers and practitioners in the field of time series analysis and forecasting, who will find it a helpful guide to their own construction of forecasting models.

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